GelTac: A Silicone Elastomer Neuromorphic Tacile Sensor Applied to Edge-Orientation Classification Tasks with a Spiking Neural Network.

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I. Introduction

Advancements in novel tactile robotic systems enables development of faster and more adaptable tools for investigating touch. This research develops a new tactile sensor to operate a streamlined Spiking Neural Network. These features cooperate towards greater understanding of how human-like touch principles can be emulated in robotics.

A. Procedure

The procedure involves an ABB robotic arm with the novel neuromorphic-based tactile sensor GelTac touching the edge of an object at varying orientations, depths and speeds. Performance is assessed through output of a neural network on classification accuracy of determining the edge orientation of the object.

II. GelTac

The GelTac (Fig. 1) is a adaptation of the base structure of the NeuroTac [1] alongside the soft, deformable gel-surface inspired by Gelsight [2]. The tip is a silicone elastomer created using Solaris Smooth-On. It is coated in a primer and a solution of white pigment, thinner and Smooth-On Ecoflex in multiple, thin layers are applied to a 6mm thick lens.

Benefits of this new approach relative to the previous NeuroTac include removing the internal deflection pins previously required for camera-event activation, greater uniform luminosity from the LEDs and a thinner, more lightweight surface material of the Solaris. Together these benefits pave the way towards more a human-like fingertip structure.

Fig. 1. GelTac prototype with 3d-printed shell and camera case, silicone lens hood and rubber-like elastomer cover

The tip is encased within a solid 3d printed TacTip [3] shell housing an event-based camera. Relative to the NeuroTac in which light is shone direct from base to surface, a thin ring of COB lead filament LED encircles the underside of the lens in the GelTac. The resulting light distribution is more balanced across the whole lens and offers greater clarity on surface deformation.

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III. Spiking Neural Network

Data is obtained through the event-based camera with individual pixel activity equated to neuron spike times (see [4] for a detailed explaination of this technique) and then processed using a Spiking Neural Network (SNN). The networks utilises STDP principles to for unsupervised learning on repeated test samples between the hidden and output layers of a 3-layer SNN. We also incorporate an additional Hebbian-inspired teaching signal throughout the network to affect the STDP weight learning speed on correct classification.

IV. Preliminary results

Early data indicates unique markers in terms of spike train activity, and synaptic weight connections, between the classification incidents. Fig. 2 illustrates the progress of weight refinement after 10 trials. Work on the spike output and classification performance of the SNN is currently ongoing.

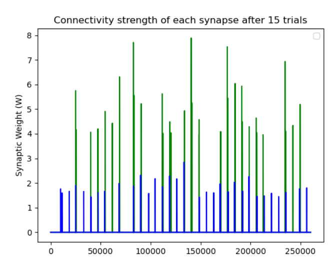

Fig. 2. Weight values of synaptic connectivity after 10 trials (green) relative to after 1 trial (blue) of the same angle orientation.

References

[1] Ward-Cherrier, B., Pestell, N., Lepora, N. F. (2020). Neurotac: A Neuromorphic Optical Tactile Sensor applied to Texture Recognition. 2020 IEEE International Conference on Robotics and Automation (ICRA). doi:10.1109/icra40945.2020.919

[2] Johnson, M. K., Cole, F., Raj, A., Adelson, E. H. (2011). Microgeometry capture using an elastomeric sensor. ACM Transactions on Graphics, 30(4), 1. doi:10.1145/2010324.1964941

[3] Lepora, N. F., (2021). Soft Biomimetic Optical Tactile Sensing With the TacTip: A Review. IEEE Sensors Journal, 21(19): 21131–21143. doi:10.1109/JSEN.2021.3100645.

[4] Macdonald F. L. A., Lepora N. F., Conradt J., Ward-Cherrier B. Neuromorphic Tactile Edge Orientation Classification in an Unsupervised Spiking Neural Network. Sensors. 2022; 22(18):6998. doi.org/10.3390/s22186998